Astigmatic Refractive Error: The Power Cross

Basic Optics, Chapter 15
Power Cross

- The power cross is a concise and convenient format for representing astigmatic error (and its correction)
- It’s also a source of considerable confusion for ophthalmologists-in-training
- Trust me when I say that, once you understand it, the Power Cross is your friend!
A cylinder can be represented on a power cross. Note the notation conventions: Power is recorded on the *meridian* of power, which is $90^\circ$ away from the *axis* of power. In this way, a power cross provides an efficient summary of the clinically relevant refractive properties of the cylinder.
If you have difficulty remembering the conventions of power-cross notation (i.e., that the power is notated at the meridian of power, 90° away from the axis of power)…
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...then picture it this way; i.e., as a cylinder oriented along the notated axis of power. Visualized this way, the meridian of power is obvious!
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The component cylinders can be written as individual power crosses...

**+2 x 090**

**+3 x 180**
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The component cylinders can be written as individual power crosses...

...and the individual power crosses can be combined into a single cross that represents the lens in its entirety.
Power Cross

Here’s where confusion concerning power crosses creeps in. The most common mistake is to treat the power cross like a spectacle/CL prescription. In the present example, the power cross could be (mis)interpreted as representing the spectacle correction $+3 +2 \times 090$, or perhaps $+2 +3 \times 180$. 
Here’s where confusion concerning power crosses creeps in. *The most common mistake is to treat the power cross like a spectacle/CL prescription.* In the present example, the power cross could be (mis)interpreted as representing the spectacle correction +3 +2 x 090, or perhaps +2 +3 x 180.

Note that +3 +2 x 090 and +2 +3 x 180 cannot both be correct, as they are not equivalent refractions:

- +3 +2 x 090 converts to +5 -2 x 180 (not +2 +3 x 180); likewise,
- +2 +3 x 180 converts to +5 -3 x 090 (not +3 +2 x 090)
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What’s the difference between a power cross and a prescription? A prescription is written in spherocylindrical form, whereas a power cross is written in cylinder form only. If you break down the word ‘spherocylindrical,’ you can see that a prescription is composed of a sphere power (the first number) and a cylinder power (the second number, and its axis). In contrast, a power cross simply states the power and axes of two cylinders—no spherical power is implied.
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This states ‘the entire lens has a base power of +3, and +2 of cylinder power with axis 090 has been added.’ (Note that this means the lens has a total of +5D power at axis 090--the base +3 plus the cylindrical +2.)

This states ‘the entire lens has a base power of +2, and +3 of cylindrical power with axis 180 has been added.’ In this version, the lens has a total of +5D power at axis 180 (the base +2 plus the cylindrical +3).
Here’s where confusion concerning power crosses creeps in. The most common mistake is to treat the power cross like a spectacle/CL prescription. In the present example, the power cross could be (mis)interpreted as representing the spectacle correction $+3 + 2 \times 090$, or perhaps $+2 + 3 \times 180$.

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You can see that neither of these is a proper interpretation of the power cross below:

This states ‘the entire lens has a base power of +2, and +3 of cylindrical power with axis 180 has been added.’ In this version, the lens has a total of +5D power at axis 180 (the base +2 plus the cylindrical +3).
Here’s where confusion concerning power crosses creeps in. The most common mistake is to treat the power cross like a spectacle/CL prescription. In the present example, the power cross could be (mis)interpreted as representing the spectacle correction \( +3 \times 180 \), or perhaps \( +2 \times +3 \times 180 \).

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In contrast, this is simply stating ‘the lens has a power of +2 at axis 090 and +3 at axis 180.’
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This is true even if the power-cross format is being used to describe a spherocylindrical lens!
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Power Cross

A power cross can easily be converted to its spherocylindrical equivalent. Simply pick one of the cylinders to serve as the basis for the spherical component, then adjust the power of the other cylinder as needed. For instance, in the present example we could use +2D as our base sphere. The power needed at axis 090 is now in place. What about at 180? Since there is already +2D present there (courtesy of our +2D base sphere), we need an additional +1 x 180 to produce the +3D power needed in this axis. Thus, if using a +2D base sphere lens, the spherocylindrical (prescription) equivalent of our power cross is +2 +1 x 180.
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Or, we could use the +3D cylinder to create our base sphere. Note that this provides 1D of plus more than is needed at axis 090. To offset this excess plus we need -1 x 090 to produce the power needed in this axis. Thus the spherocylindrical (prescription) equivalent would be +3 -1 x 090.
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Note the two prescriptions are equivalent:

+2 +1 x 180 converts to +3 -1 x 090, and
+3 -1 x 090 converts to +2 +1 x 180.
Let’s take more of a cookbook approach to the conversion of a power cross to a spherocylindrical correction. Here’s how to convert a power cross into a spherocylindrical prescription in four easy steps!
**Power Cross**

1. *Separate the cylinders.*

![Diagram of Power Cross](image)

- Power Cross
- 135
- 45
- +3
- 0
- +2
- 135
- 45
- +3
- 0
- +2
Power Cross

1. Separate the cylinders.

2. Make one cylinder the sphere by adding its power to the other arm.
Power Cross

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2. Make one cylinder the sphere by adding its power to the other arm.

3. Subtract the same amount from the same arm of the other cylinder.
Power Cross

1. Separate the cylinders.

2. Make one cylinder the sphere by adding its power to the other arm.

3. Subtract the same amount from the same arm of the other cylinder.

4. Combine the two into the spherocylindrical correction:

\[
+3 -1 \times 045
\]

\[
+3 - (+3) = +3
\]

\[
+2 - (+3) = -1
\]
We’ve seen this slide before: It was the final result of our Jackson cross refraction exercise. Let’s use it as a test of our new-found power cross skills by checking the final result against what would be expected on the basis of the eye error…
Power Cross

Eye Error:  
+1 x 180  
+5 x 090

**Power cross for correction:**

+4x180  
-5 Sph

(That is, if **this** is the power cross of the eye error, what would the power cross for the correction be? Disregard vertex distance.)

**Check our work...**

*Misleading figure!*
Eye Error:
+1 x 180
+5 x 090

Power cross for correction:
-1 x 180
-5 x 090

Check our work…
Power Cross

Eye Error:
+1 x 180
+5 x 090

Power cross for correction:
-1 x 180
-5 x 090

+4x180
-5 Sph

Check our work...
Power Cross

Eye Error:
+1 x 180
+5 x 090

Power cross for correction:
-1 x 180
-5 x 090

Check our work...

+4x180
-5 Sph

To combine the power crosses into a spherocylindrical equivalent, first add -5 x 180 to the -5 x 090 lens. (This will make -5 the sphere component of the Rx.)
Power Cross

Eye Error:
+1 x 180
+5 x 090

Power cross for correction:
-1 x 180
-5 x 090

To combine the power crosses into a spherocylindrical equivalent, first add -5 x 180 to the -5 x 090 lens. (This will make -5 the sphere component of the Rx.)

To keep things in balance, subtract that same -5 x 180 from the other power cross, resulting in a power of +4 x 180 (remember, minus a minus is a plus).
To combine the power crosses into a spherocylindrical equivalent, first add $-5 \times 180$ to the $-5 \times 090$ lens. (This will make $-5$ the sphere component of the Rx.) To keep things in balance, subtract that same $-5 \times 180$ from the other power cross, resulting in a power of $+4 \times 180$ (remember, minus a minus is a plus).

So the spherocylindrical correction for this eye error is $-5 + 4 \times 180$, which is exactly what we got with the Jackson cross refraction!

Check our work… Cha-Ching!
Your turn. These are refractive results (not eye errors). Convert each power cross to spherocylindrical spectacle prescriptions in both plus and minus cylinder formats. Then calculate the S.E. (or can you determine the S.E. simply by looking at the power crosses?)
Power Cross

If we let the base sphere be +1D...
Power Cross

If we let the base sphere be +1D… we will need an extra +1D at axis 090 to get the +2 power needed there.

*Plus cyl:* \(+1.0 \ +1.0 \times 090\)
Power Cross

If we let the base sphere be +2D...

Plus cyl:  +1.0 +1.0 x 090
           +2.0

Minus cyl: +2.0 –1.0 x 180

S.E.:   +1.50
Power Cross

If we let the base sphere be +2D… we will need a -1D at axis 180 to get the +1 power needed there.

Plus cyl:  +1.0 +1.0 x 090
Minus cyl: +2.0 –1.0 x 180
Power Cross

Plus cyl: +1.0 +1.0 x 090
Minus cyl: +2.0 –1.0 x 180

Spherical equivalent = ?
Power Cross

Plus cyl: +1.0 +1.0 x 090
Minus cyl: +2.0 –1.0 x 180

Spherical equivalent = +1 + (+1)/2 = +1.50
Power Cross

\[ \text{Spherical equivalent} = +1 + (+1)/2 = +1.50 \]

**Plus cyl:** +1.0 +1.0 x 090

**Minus cyl:** +2.0 –1.0 x 180

\[ \text{Spherical equivalent} = ? \]
Power Cross

Plus cyl: \(+1.0 + 1.0 \times 090\)

Minus cyl: \(+2.0 - 1.0 \times 180\)

Spherical equivalent = \(+1 + (+1)/2 = +1.50\)

Spherical equivalent = \(+2 + (-1)/2 = +1.50\)
Power Cross

**Plus cyl:**  +1.0 +1.0 x 090
**Minus cyl:** +2.0 –1.0 x 180
**S.E.:** +1.50
Power Cross

If we let the base sphere be -8D…
Power Cross

If we let the base sphere be -8D…
we will need an extra +4D at axis 045
to get the -4 power needed there.

Plus cyl: -8.0 +4.0 x 045
Power Cross

If we let the base sphere be -4D…

Plus cyl: -8.0 +4.0 x 045
-4.0
Power Cross

If we let the base sphere be -4D... we will need an extra -4D at axis 135 to get the -8 power needed there.

Plus cyl:  -8.0 +4.0 x 045
Minus cyl: -4.0 –4.0 x 135
Power Cross

**Plus cyl:**  
-8.0 +4.0 x 045

**Minus cyl:** -4.0 –4.0 x 135

Spherical equivalent = ?
Power Cross

Plus cyl: \(-8.0 + 4.0 \times 0.45\)
Minus cyl: \(-4.0 - 4.0 \times 135\)

Spherical equivalent = \(-8 + (+4)/2 = -6.0\)
Power Cross

Plus cyl: $-8.0 + 4.0 \times 045$

Minus cyl: $-4.0 - 4.0 \times 135$

Spherical equivalent = ?
Power Cross

Plus cyl: \(-8.0 + 4.0 \times 45\)

Minus cyl: \(-4.0 - 4.0 \times 135\)

Spherical equivalent = \(-4 + (-4)/2 = -6.0\)
Power Cross

Plus cyl: -8.0 +4.0 x 045
Minus cyl: -4.0 –4.0 x 135
S.E.: -6.0
Power Cross

If we let the base sphere be -4D…
Power Cross

If we let the base sphere be -4D…
we will need an extra +12D at axis 135
to get the +8 power needed there.

Plus cyl: -4.0 +12.0 x 135
Power Cross

If we let the base sphere be +8D…

Plus cyl: -4.0 +12.0 x 135 +8.0
Power Cross

If we let the base sphere be +8D… we will need an extra -12D at axis 045 to get the -4 power needed there.

Plus cyl: -4.0 +12.0 x 135
Minus cyl: +8.0 –12.0 x 045
Power Cross

Spherical equivalent = ?

Plus cyl: -4.0 +12.0 x 135
Minus cyl: +8.0 –12.0 x 045
Power Cross

Spherical equivalent = -4 + (+12)/2 = +2.0

Plus cyl: -4.0 +12.0 x 135
Minus cyl: +8.0 –12.0 x 045
Power Cross

Plus cyl: -4.0 \(+\)12.0 \(\times\) 135

Minus cyl: +8.0 \(-\)12.0 \(\times\) 045

Spherical equivalent = ?
Power Cross

Spherical equivalent = \( +8 + (-12)/2 = +2.0 \)

\[ Plus \text{ cyl: } -4.0 + 12.0 \times 135 \]
\[ Minus \text{ cyl: } +8.0 - 12.0 \times 045 \]
Power Cross

Plus cyl: -4.0 +12.0 x 135
Minus cyl: +8.0 –12.0 x 045
S.E.: +2.0
Note that the S.E., being at the ‘dioptic center’ of the conoid of Sturm, is simply the halfway point between the two cylinder powers. This can be determined by averaging the cylinder powers—converting to spherocylindrical form first is unnecessary.